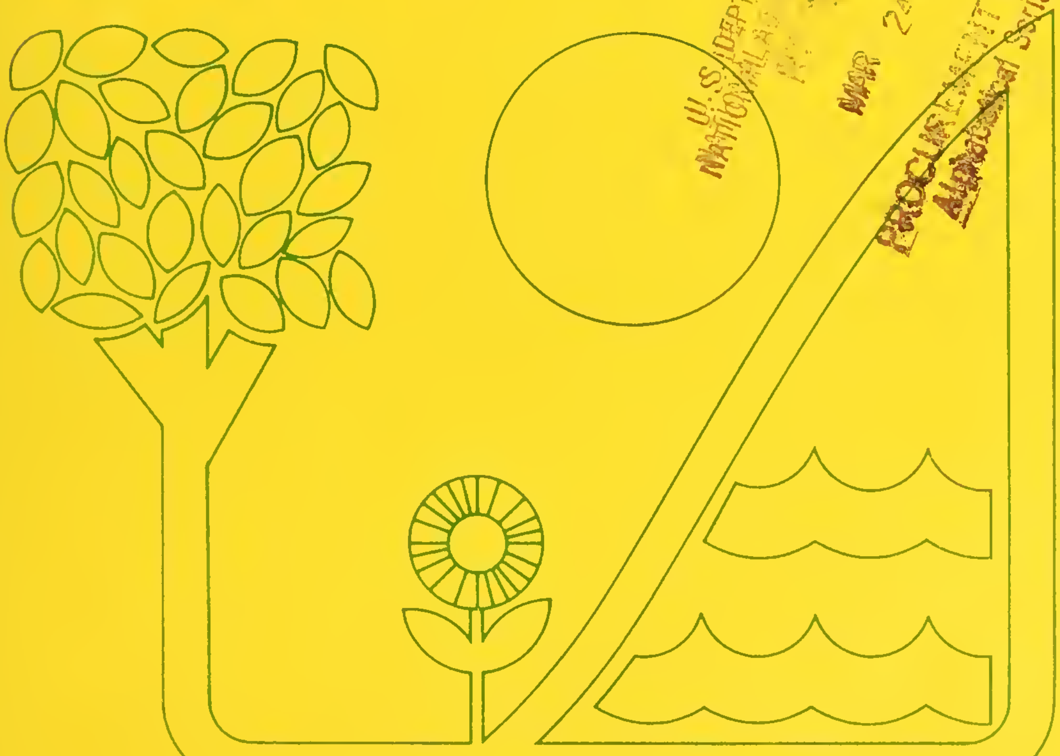
FOR DISCUSSION ONLY

WORKINGPAPER

NRE ECONOMIC RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE



NUMBER #13

Notes on Conserving Energy in Irrigation

Dallas M Lea

May 1976

May 1, 1976

NOTES ON CONSERVING ENERGY IN IRRIGATION

by

Dallas M. Lea
Agricultural Economist, ERS, NRED

Irrigation pumping energy requirements are a function of:

1. The volume of irrigation water pumped.
2. The feet of lift--the elevation difference between the water source and the field being irrigated.
3. The efficiency of the irrigation system (percentage of the water applied that is stored in the root zone). 1/

Therefore, everything else equal, pumping energy can be conserved by reducing the volume of irrigation water and the irrigation lift, and employing an irrigation system that utilizes the lowest pumping pressure to achieve a given level of irrigation efficiency.

Irrigation water and subsequently pumping energy can be conserved by applying an adequate amount of water at the proper time. This requires the scheduling of irrigation water applications for increased efficiency and thereby maximizing profit. Of course many variables of climate, soils, and crops are involved. Principal among these are temperature, radiation, wind conditions, water holding capacity of the soil, soil moisture, rate of water use by crops, etc., all of which must be considered in irrigation scheduling for best results.

The two sources of irrigation water are surface and groundwater. Surface water has a lower pumping lift than groundwater and will naturally be used as the irrigation water source when available. However, groundwater is often the only available source and must per force be used.

Irrigation systems

The American Society of Civil Engineers recently published an article giving the per acre energy required for nine irrigation systems based on 36 inches net irrigation requirements and zero pumping lift. 2/ Energy required for installation, pumping, labor, and total are shown as follows:

1/ Another efficiency term associated with irrigation, pumping efficiency, refers to the efficiency of the pumping unit expressed as a percentage.

2/ Batty, J. Clair, Hamad, Sofa N., and Keller, Jack; "Energy Inputs to Irrigation," Journal of the Division of Irrigation and Drainage, Dec. 1975.

Irrigation System	Energy required per acre			
	Installation 3/	Pumping	Labor	Total
	Thousand kilocalories			
1. Surface (gravity) without irrigation runoff recovery system	103.2	35.2	0.50	138.9
2. Surface with irrigation runoff recovery system	179.9	48.0	0.30	228.2
3. Hand-moved sprinkle	159.7	804.0	4.80	968.5
4. Trickle	530.5	468.0	0.10	998.6
5. Side-roll sprinkle	200.3	804.0	2.40	1,006.7
6. Center-pivot sprinkle	388.5	864.0	0.10	1,252.6
7. Permanent sprinkle	493.6	770.0	0.10	1,263.7
8. Solid-set sprinkle	614.1	770.0	0.40	1,384.5
9. Traveler sprinkle	288.9	1,569.0	0.40	1,858.3

3/ Includes energy used in manufacturing all materials, machinery, and a pro rata share of excavation machinery used, and the energy required to operate excavation machinery. Energy required to transport materials, machinery, or labor was not included.

The same article stated, "The volume of irrigation water needed is independent of the type of irrigation system used, but the gross volume of water that must be pumped or delivered is a function of the irrigation efficiency which, in turn, depends on the irrigation system. Generally speaking, the efficiency of simple surface irrigation systems varies between 30%-70% with 50% as an average value. However, an efficiency of about 85% can be obtained by using an irrigation Runoff Recovery System. Sprinkle irrigation efficiencies vary between 60% and 90%, with an average of 70%. The efficiency of trickle irrigation systems varies from 75%-95%, with an average of about 80%."

The above data indicate that while surface irrigation systems are less efficient than either trickle or sprinkle systems, their operation requires much less energy. The efficiency of surface systems can be improvedby the addition of an irrigation runoff recovery system. However, the energy required per unit of water delivered to the root zone is approximately the same and results in only a small net energy saving.

Trickle irrigation has the next lowest pumping energy requirement, but due to high installation energy use, it ranks fourth in total energy requirements after hand-move sprinklers, which is third lowest in total energy. Side-roll sprinklers rank fifth in total energy use followed by center-pivot. Traveler sprinkle systems are the biggest energy consumers by far because of grossly high pumping energy requirements. Perhaps it should be noted that differential energy costs were not considered in the above table. If, for example, labor costs were comparatively high per unit of energy, that would probably shift the rankings of hand-moved sprinklers and side-roll sprinklers significantly from the standpoint of total cost because of their higher labor requirements.

Sprinkler systems commonly operate on pumping pressures of 65 to 85 psi compared to 6 to 10 psi for gated pipe or surface systems. The higher pumping pressure accounts for much of the higher energy pumping requirements by sprinkler systems. Therefore, any practice that materially reduces the pressure of sprinkler systems without a corresponding change in irrigation water distribution would result in a significant net energy saving. Dr. W. E. Splinter, Chairman of the University of Nebraska Department of Agricultural Engineering says that nozzle design is probably the key factor in reducing energy cost for sprinkler irrigation. 4/

"During hot, windy, dry Nebraska summers, there is not only severe pattern distortion but high evaporative losses. We calculate that for 105° F, 10% RH and an 8 gpm nozzle, 60 psi and 20 mph wind, there would be a 38% evaporation loss. Reducing pressure to 30 psi with an 8 gpm nozzle reduces evaporation to 15%. Going to a 25 gpm nozzle operated at 30 psi under these conditions would reduce losses to 7%. Since it is water on the ground that counts, any evaporative loss is an energy loss. Operating a center pivot at 40 psi at the pivot with a 5 HP boost pump at the last tower might be one way to save considerable energy. Larger droplet size would also reduce pattern distortion..."

"Increasing pipe size on sprinkler systems from 6 5/8 inch ID (inside diameter) to 8 inch would cut friction losses by half while increasing diameter to 10" would cut friction losses to 1/10." However, this would have the adverse effects of increasing weight and initial cost and would, because of the added weight, have limitations as an energy conservation measure.

Dr. Splinter said, "Use of fertilizer through sprinkler systems should prove to be more efficient than by ground transport systems since

4/ Splinter, W. E.; "What's in the Future for Sprinkler Irrigation?" Irrigation Age, March 1975.

distribution can be timed to accommodate crop needs, thereby decreasing leaching, erosion losses (and saving energy). The application of herbicides through sprinkler systems, again, looks promising and we see no reason but what a broad range of herbicides cannot be so applied." This would conserve still more energy.

Dr. Splinter stated that adoption of re-use pits to capture tail water and the development of automated gated pipe systems, which allow short cycling of sets, allows the surface irrigator to apply water at over 90% efficiency.

Scheduling

Dr. Splinter expressed the belief that the new frontier in saving both water and energy in irrigation is through scheduling applications of irrigation water.

"Some success in scheduling has been achieved by rather simple procedures. Scheduling by stage of growth, by moisture block readings, by a simple ET method and even by applying 3 inches every 14 days proved successful at the University of Nebraska Mead Field Lab last summer.

"For two summers, we have had good success in a cooperative program with one of the electric coops in reducing peak electrical demands by scheduling both center-pivot and gravity systems. A commercial firm monitored soil moisture level and advised the coop and the farmers as to amounts of moisture in the soil."

Another article by the editor of that same publication appeared one year later giving the latest developments in irrigation scheduling. 5/ During 1975, a system was developed in 3 Nebraska counties in which farmers could dial a "hot line" number in the county Agricultural Extension Service office and receive a tape-recorded message giving the latest information by crops on the total and average daily use of water over the last several days. This information is developed by feeding daily readings of temperature, radiation, relative humidity, and wind velocity into a computer that, in turn, produced readouts on daily water use requirements (evapotranspiration) for corn, alfalfa, and irrigated pasture. The message tapes are updated with this information every 3 days. Farmers in the area used this information to schedule their irrigation and make adjustments in their irrigation equipment controls for the most efficient results. One county extension office received 270

5/ Ross, Ron; "Scheduling Irrigation by Telephone Hot Line," Irrigation Age, March 1976.

calls on its "hot line" during the July thru September irrigation season, which is sufficient testimony of the program's usefulness, considering 1975 was the first year it was in operation. Plans are underway to expand this service in Nebraska and into Colorado. Hopefully it will become a standard service in all irrigating areas that have facilities available for its implementation. Also, there are several types of soil moisture measuring instruments in use with which farmers can monitor irrigation water use and schedule their irrigation applications accordingly for the most efficient use of both water and energy.

Where electricity is the energy source for irrigation pumping, it is becoming a fairly common practice to schedule some of the irrigation at night in order to reduce the peak load on the power facility. While that does not conserve energy, it reduces electric power generating capacity needs. It also results in reduced price rates for electricity since the rates in many instances are based on the highest peak loads. Night irrigation might also result in the additional benefit of less evaporation water loss, but that factor has not been researched or quantified.

Other energy conservation measures

1. Proper maintenance and lubrication of all irrigation machinery to avoid reduced pumping efficiency.
2. Proper pumping plant adjustments to match the pump with the lift. Matching pump impellers, pulleys (RPM), and motors to reflect lift and system pressure needs can increase efficiency as much as 20%-30%.
3. Lining canals and ditches to reduce pumped water loss because energy saved is roughly proportional to water saved.
4. Land leveling to reduce water requirements and subsequently energy requirements, especially in surface irrigation. However, land leveling is an energy intensive operation and is, therefore, limited as an energy conservation practice.
5. Proper consideration of water diversion locations where alternatives exist to take advantage of gravity flows.

According to a study by Sloggett 6/ of ERS, natural gas is the cheapest source of irrigation pumping energy per acre and per acre-foot of irrigation water followed by electricity, diesel, liquid propane gas, and gasoline in that order. However, measured in BTU's of energy consumed

---

6/ Sloggett, Gordon; "Energy Used for Pumping Irrigation Water in the U.S., 1974," preliminary paper, February 1976.

per acre irrigated, natural gas is the leader in energy expended by a rather large margin. Electricity (not including BTU's used to generate the electricity) consumes the least BTU's per acre in irrigation pumping followed by diesel, liquid propane, gasoline, and then natural gas.

While there is some research underway regarding irrigation pumping energy used by crops, efforts to obtain published research results on that subject have been unsuccessful. Until such research is documented, it appears that the best approach to conserving irrigation pumping energy is by conserving irrigation water applied (without reducing yield) because of the direct correlation between water saved and energy saved.